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Using Heart Rate to Predict Resilience and Susceptibility to PTSD in Soldiers

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ABSTRACT

The purpose of this paper is to consider the use of heart rate as a potential indicator for predicting both susceptibility and resilience in Soldiers who have not yet deployed. Previous research shows positive correlations among stress, negative emotions, heart rate, and PTSD in individuals diagnosed with this disorder. Often times, those with PTSD show increased heart rate when exposed to images that replicate a traumatic situation. Based on these findings, we hypothesize that exposing Soldiers without any past history of PTSD to traumatic images prior to deployment will cause the ones most susceptible to PTSD to experience significantly higher heart rates. Those with the lowest heart rates would potentially be more resilient and thus be less likely to return from deployment with PTSD. Heart rate measurement would augment the measures used in the Comprehensive Soldier Fitness program and provide a more holistic picture of a Soldier's psychological fitness.

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CONTENTS

	Page
INTRODUCTION.....	1
STRESS AND POSTTRAUMATIC STRESS DISORDER.....	2
POSTTRAUMATIC GROWTH.....	3
RESILIENCE.....	4
MILITARY CONTEXT.....	6
RESILIENCE AND HEART RATE.....	8
COMPARISON METRIC STUDY 1.....	11
COMPARISON METRIC STUDY 2.....	14
PROPOSED STUDY METHOD.....	15
Participants.....	15
Apparatus and Procedure.....	16
CSF ASSESSMENT DESIGN.....	17
ANNOTATED REFERENCES.....	18

Introduction

The effects of stress are wide and vary depending on the individual. The Army has placed paramount emphasis on understanding individual and environmental factors associated with stress and posttraumatic stress disorder (PTSD) as they may impact Soldier readiness and performance. In order to better understand the psychological effects of combat exposure, an analysis of the negative effects as well as the positive effects of combat is key to recognizing the complexity of outcomes that may arise from these experiences. The ability to understand why some individuals experience posttraumatic stress disorder while others experience posttraumatic growth is critical for the Army. If the Army can develop a method to help Soldiers appraise combat exposure as a positive experience that leads to internal growth, this appraisal may result in resilient Soldiers who do not develop PTSD. With the study of PTSD, much attention is given to the concept of resilience (Rutter, 1987). Resilience is the ability of individuals to be able to resist or bounce back from adversity. The ability of Soldiers to experience traumatic events and then recover from them is vital to a Soldier's well-being.

It is critical for the armed forces to better understand the concepts of resilience and hardiness in order to best assist Soldiers who face physical and mental challenges due to combat exposure in both the short and long term. Previous research indicates that heart rate can be used to test Soldiers for resiliency against developing PTSD as well as screening for susceptibility to PTSD. Increased heart rate variability is a possible indicator of a Soldier's potential for developing PTSD and may be indicative of the length of combat exposure.

Stress and Posttraumatic Stress Disorder

Psychological stress may be viewed from at least three different models. The stimulus-based model describes stress as a function of external influence (Stokes & Kite, 1994). The second approach is a response-based model where stress is a composite of response patterns from exposure to the stressor. The third approach is a transaction model that focuses on the interaction between the individual and the environment by appraising situations and shaping responses based on those appraisals (McGrath, 1976). Although there are different models of stress, these models all emphasize that stress is multidimensional.

It is well documented that human performance is affected by stress. Although some individuals will be affected more than others, human performance generally follows the Yerkes-Dodson inverted U function when under stress (Yerkes & Dodson, 1908). When stress is introduced, facilitation occurs which has been shown to improve performance (Chappelow 1988). Yet, at a certain point stress decreases an individual's performance (Lehner, Seyed-Solorforough, O'Connor, Sak & Mullin, 1997). Stress will then have negative effects on cognition by affecting the attention, memory, and judgment of individuals. It is important to identify the balance needed for optimal performance and stress for individuals.

Although exposure to traumatic events is experienced and recorded in human history, the study of the mental and physical strain trauma brings is a relatively new field. PTSD can be defined as an exposure to an extreme traumatic stressor in which a person's response involves intense fear, helplessness, or horror and there is a persistent re-experiencing of the traumatic event with the same symptoms to that increased arousal. Studies range from understanding the role of genetic factors (Zatzick et al., 2004) to environmental influences (Stein, Jang, Taylor, Veron & Livesley, 2002) and indicate that PTSD is multifactorial. The Army is trying to

mitigate the negative effects of trauma but there are other fields of study that indicate Soldiers can actually experience positive growth due to traumatic events and bounce back to their original mental state.

Posttraumatic Growth

Although posttraumatic stress has been the focal point of research and information when dealing with combat exposure and trauma, many survivors have reported posttraumatic growth (PTG) from their experiences. The idea is that trauma and suffering can actually allow for a personal transformation that is positive in nature (Tedeschi & Calhoun, 1995). This type of growth or change is reported with many different types of traumas to include life-threatening illnesses (Heffernon, 2009; Stanton, Bower & Low, 2006), immigration (Berger & Weiss, 2006), and bereavement (Cadell & Sullivan; 2006; Znoj, 2006).

This evidence is further expanded in combat veterans who experienced PTG based on their traumatic events. The possibility that Soldiers can take a traumatic event and experience growth from it shows the potential for PTG. A critical example is how during the Vietnam War, aviators were shot down, imprisoned, and tortured for years by the North Vietnamese Army and Viet Cong. Yet over 61% said that they benefited psychologically from this traumatic event (Sledge, Boydstun & Rabe, 1980). The former prisoners of war reported that the imprisonment and hardship that they faced produced favorable changes in their personality, increased their self-confidence, and allowed them to understand what they truly value in life. The traumatic events that these Soldiers faced allowed for a positive growth to occur due to the harshness of their circumstance.

Posttraumatic growth also occurred for combat veterans of the 1973 Yom Kippur War (Solomon & Dekel, 2007). These veterans were split into either those who were once prisoners

of war or those who were not. The former POWs had more posttraumatic growth with higher levels of PTSD symptoms than those who were not captured. They found that the severity of the PTSD symptoms had a positive correlation with the degree of posttraumatic growth. This suggests that there is a possibility that the harsher the situation that an individual faces, they are more positively affected if they look at the situation positively.

The potential for PTG must be fostered in Soldiers. Current literature suggests that PTG can be promoted in Soldiers through three critical methods. First, is a model of expert companionship that focuses on the constancy of the companion, humility, and respect for the survivor's narrative and perspective, and a highlighting of strength and change (Tedeschi & Calhoun, 2006). Second, psychotherapy can nurture change through cognitive processing, supporting attempts to master new experiences, and enhancing relationships (Zoellner & Maercker, 2006). Third, is the importance of retelling a life narrative of the trauma in a story telling fashion (Meichenbaum, 2006). These strategies can allow a Soldier to reevaluate the experiences that they faced and see if they can learn positive lessons from those experiences. By implementing these strategies, Soldiers may see their combat exposure and trauma as positive events that allowed for positive growth.

Resilience

Along with posttraumatic growth there is a developing interest in the ability of individuals to resist or bounce back from adversity, or their resiliency to traumatic events. Resiliency is seen as a potential solution to help Soldiers adapt to the stresses of combat. If Soldiers are able to face adversity and cope with the stress, this could allow for Soldiers to adapt to stressful environments.

Neurochemistry plays an important role in understanding resilience. When stressful situations occur, the body releases mediators of allostasis- cortisol and adrenalin, in order to act in the short term and promote an adaption to the acute stress (McEwen & Stellar, 1998). However, if there is an allostatic overload due to too much stress, this can lead to chronic stress and deleterious consequences. Resilience is the ability to minimize allostatic load by switching off the allostatic stress response when the actual stressor has ended (Southwick et al., 2008).

With the current viewpoint of what resilience is and how prevalent PTSD is in the news, many have the misperception that PTSD and PTSD-like symptoms are common for Soldiers overseas and others who face traumatic events. Yet, resilience is the most frequently observed outcome when an individual faces a traumatic event. One critical example was an experiment conducted on residents of the New York Metropolitan area during the first six months after the September 11th terrorist attacks (Bonnano et al., 2005). Using random phone surveys, investigators got a sample size that mirrored the census data for the New York area (Galea et al., 2003). The survey found that nearly two-thirds of a large probability sample size (N=2752) was resilient to the attacks. This was true even when the sample was narrowed to only include the people who witnessed the attack in person or was directly affected through injury or loss of a friend or loved one; more than 50% of this sample showed resilience. This shows that most people, although they may be affected from the traumatic event, can bounce back or are not affected by the events and are resilient within the first six months after the event (Resnick, Galea, Kilpatrick & Vlahov, 2004). Resilience is the most likely response to traumatic events with PTSD and PTSD symptoms only occurring in a small percent of individuals.

In order to foster resilience in Soldiers there is a focus on positive psychology that emphasizes on building a science of human strength, virtues, and how one sees the world. This

starts with person-centered factors of an individual's personality dimensions. There are two broad categories of person-centered factors: flexible adaptation and pragmatic coping (Bonanno, 2004). Flexible adaptation is the capacity to shape or modify a person's behavior to meet the demands of a given stressor. There are two different types of flexible adaptations which are appraisal-based and expressive. Appraisal-based flexibility is the ability of an individual to reduce the negative impact of stressful situations by appraising them in a manner that promotes active engagement and allows individuals to protect and promote their sense of self-esteem and self-efficacy. Expressive flexibility is the ability to allow intrapersonal and interpersonal changes in response to a stressor by regulating the expression of emotion based on the situation. Pragmatic coping is the single-minded goal of coping strategies where an individual will do whatever it takes when responding to a traumatic event (Bonanno, 2006). By developing the personality traits of individuals, resilience can be better adapted to traumatic events. If Soldiers see situations in a positive light and adjust to stressors in that manner, they can build more resilience to these stressful events.

Military Context

The study of the effects of combat exposure started in World War II and continually expands. In World War II, the mental strain faced by Soldiers was explained as "shell shock" from the artillery rounds that were fired near a Soldier. The Army then attributed psychological symptoms to "battle fatigue" in World War II. This showed that the military started to understand that some psychological injuries could actually be cured with rest and down time from constant combat exposure. They also learned an important lesson of treating psychological casualties in theater with supportive therapy and expectation to return to duty which allowed for a majority of Soldiers to come back onto duty, while those who were treated at hospitals or

psychoanalysis were unable to return to the frontlines due to their worsening mental state (Jones, 1995). This same model was used in the Korean War as well.

Currently, the Army continues their efforts to improve the quality of mental health for Soldiers who experience psychological problems due to combat exposure. The military formed Mental Health Advisory teams (MHATs) that focus on not only protecting Soldiers in the short-term from issues related to combat exposure but also focuses on the long-term as well. These teams found that for Soldiers in Iraq in the fall of 2003, 7.3% showed signs of anxiety, 6.9% showed signs of depression, and 15.2% showed signs of posttraumatic stress (Mental Health Advisory Team, 2003). Mental health problems are experienced not only by war fighters in Iraq (19.1%) but are experienced by war fighters in Afghanistan (11.3%), and other operations worldwide (8.5%) (Hoge, Auchterlonie & Milliken, 2006).

Studies like the one conducted by the MHATs and Hoge et al. (2006) support the need for the Army to develop resilience in Soldiers. The Army is already helping Soldiers deal with battlefield stress using the principles of combat and operational stress control (COSC). The COSC doctrine is focused on enhancing adaptive stress reactions, preventing maladaptive stress reactions, and helping Soldiers with behavioral or psychiatric disorders. This and other recent initiatives such as the Comprehensive Soldier Fitness Program show the importance that the Army is placing on assisting Soldiers adjust to the stresses of combat. If the Army can find a metric or indicator as to who may be likely to develop posttraumatic stress disorder, posttraumatic growth, or resilience and evaluate this within the auspices of the Comprehensive Soldier Fitness (CSF) program, the CSF may better assist Soldiers exposed to combat.

Resilience and Heart Rate

With the information we have on PTSD and resilience, it is our goal to provide a metric that will enable the United States Army to potentially recognize specific individuals who are susceptible to or more resilient to PTSD, specifically heart rate. From a basic biological perspective, any stressful situation, especially the traumatizing events of war, spark many physical changes in the human body. The system affected is the sympathetic adrenomedullary system consisting of the sympathetic nervous system and adrenal medulla. The sympathetic nervous system controls the involuntary actions in the body when high levels of stress are involved. Elevated heart rate occurs when there is a release of epinephrine, a hormone found in the adrenal medulla right above the kidney (Kemeny, 2003). From a physiological perspective, we hypothesize that more resilient individuals will show a lower heart rate when exposed to traumatic images. This would reveal a lower level of stress and potentially a lower susceptibility to PTSD after actually experiencing a traumatic combat situation.

During an extremely stressful situation, there are emotional changes that inevitably take place as well. Brosschot & Thayer (2003) discovered that there was a higher heart rate level in participants showing negative emotions than those with positive emotions. The importance of this study is that heart rate can be specifically tied to negative emotions and that there is a distinct difference in the heart rate level between positive and negative emotions. PTSD is viewed as being tied with many negative emotions and with results like this, it is not a stretch to believe that susceptibility to PTSD could be tested for by measuring heart rate after exposure to something traumatic. If heart rates across the board are elevated in most participants for one reason or another, differentiation can be achieved through the length of elevated heart rate. This point is demonstrated in a study done by Kibler & Lyons (2004) using combat veterans as

participants. Their research demonstrated that “heart rate recovery was the only physiological variable significantly related to PTSD severity.” From this we could expect to see that Soldiers with a potential for resiliency may initially show elevated heart rates but those high readings would drop significantly faster than those more prone to PTSD.

Another study done by Driscoll et al. (2009) revealed that participants who tried to decrease emotions from the presented categories of stimuli showed “a greater heart rate deceleration as compared to increasing emotion.” A key finding was that “when attempting to down-regulate emotion, most participants reported reducing attention to the more salient aspects of the stimuli” (Driscoll et al., 2009). This could very well indicate resilience in the participants as they are effectively blocking out what they don’t want to take in and consequently, lowering their heart rate simultaneously.

Coping ability is thought to play a large part in the outcome and Kibler & Lyons (2004) found that the veterans’ coping abilities were “highly correlated with PTSD severity and heart rate recovery.” This merely makes the point clear that there is much more to a diagnosis of PTSD than a simple comparison of heart rate and PTSD. This also demonstrates that individual coping levels should also be taken into account in the proposed study.

Nagamine et al. (2007) found that people with a history of PTSD tend to have a much stronger relationship between heart rate and emotional memory. The results indicated that the stronger the emotional memory, the higher the heart rate in those with PTSD. The authors speculated that “a heightened pre-HR would be accompanied with an emotional state during the anticipatory period.” This correlation will be a critical consideration in the proposed test as the Soldiers are exposed to traumatic images and videos. High heart rate and emotions such as fear or anger could go hand in hand as signs of susceptibility. Soldiers remaining calm and letting

those images “roll off their backs” could be candidates supporting the success of the Army’s resiliency training program and could provide valuable data for the Army’s assessment tests (Lester, 2009).

There are, however, a few things that must be taken into consideration before using heart rate as a predictor of resilience or susceptibility to PTSD. Kraemer et al. (2006) conducted a study on heart rate and the prediction of PTSD in victims of accidents. They concluded that due to the complexity of a diagnosis for PTSD, “initial heart rate measured in a clinical setting is a weak and not independent predictor of PTSD following accidental injuries.” What this says for our study, is that with the data found, it cannot be used as standalone evidence for resiliency or susceptibility and should not be used to affect the status of Soldiers. Heart rate should merely be used as a flag to make the Army aware of potentially susceptible individuals and should be used in conjunction with other tests as part of the Comprehensive Soldier Fitness assessment.

It must be noted that additional studies suggest that in certain situations, heart rate is a significant predictor of PTSD. Zatzick et al. (2005) did their own study on emergency department heart rate and how that correlated to PTSD growth in participants. They concluded that “elevated emergency department HR greater than or equal to 95 was an independent predictor of PTSD symptom development over the course of the year after injury” in patients who had been hospitalized due to some form of injury. This reveals that while HR may be an independent predictor of PTSD in some specialized cases, it took a year of observation, something not very practical for the Army’s assessment program.

With that, our initial judgment stands that heart rate should be used in conjunction with some other form of measurement to ensure accuracy. The evidence for this is further strengthened in a study done by Olsson et al., (2008) which attempted to predict PTSD

development after an accident and hospitalization. They emphasized combining the Child Trauma Screening Questionnaire (CTSQ) in addition to the heart rate results. They found that “when HR and the CTSQ were combined it was observed that a ‘both positive’ profile on the combined CTSQ-HR was more efficient at screening for children likely to develop PTSD symptoms than either the CTSQ or HR alone.”

The initial test we propose utilizes Soldiers from eight Army brigades. Soldiers will be placed in an auditorium or other large facility with heart rate monitoring equipment attached to them. They would then view a series of slides and footage showing wounds, mutilation, surgeries, and combat injuries. Details of the methodology are discussed later in this paper. We propose that Soldiers showing extremely elevated heart rates and/or a lengthy period of elevated HR while being exposed to traumatic images and videos are more susceptible to PTSD and those with lower heart rates and/or a shorter period of elevated heart rate will be found to be more resilient to PTSD in a combat environment.

Comparison Metric Study #1

Much of this metric was developed by analyzing two studies done with similar methods. Elsesser, Sartory & Tackenberg (2004) designed a fairly similar experiment which in which they measured heart rate, attention, and startle response while the participants were shown trauma-relevant pictures. Their research focused on the difference between recent trauma victims and patients with PTSD. Eighty six participants were used, thirty seven of which had experienced some kind of traumatic experience in the previous six weeks. Eighteen of the 86 had PTSD and 31 were healthy and acted as the control group. The trauma patients experienced various types of trauma related incidents to include accidents, robbery, witness of accident or suicide, fire, death of family member, and rape. The PTSD patients were diagnosed due to a specific phobia,

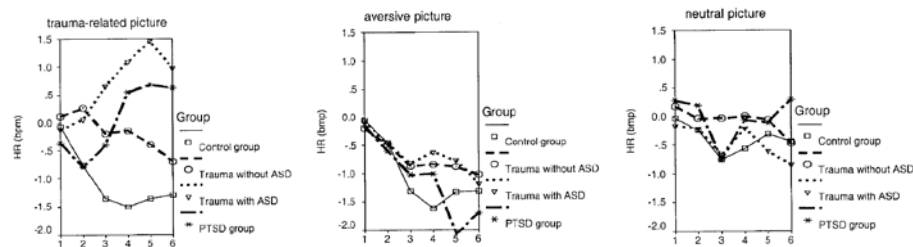
panic disorder or agoraphobia, and depression. None had experienced combat in either the recently traumatized group or the PTSD group.

Elsesser et al. (2004) first identified what type of traumatic event the participants experienced and from that information, idiosyncratic images were collected to match the individual's specific situation. Each participant was clinically assessed by a psychologist using a structured interview. Interviews took about an hour and then participants completed a questionnaire which lasted approximately thirty minutes. The researchers conducted a dot probe task, recorded the heart rate and startle reactions of the participants both when the pictures were being presented and when they were not and had them rate the images they were being exposed to. This procedure was done in the same order for everyone. Multiple questionnaires were used to include the State-trait Anxiety Inventory (STAI), the Beck Depression Inventory (BDI) and the Impact of Event Scale Revised (IES-R). The STAI rates the subject from 20 to 80, or none to high stress. The BDI uses ranges to indicate depression with 11-17 showing mild depression and 18+ as severe depression. The IES-R contains three subscales of PTSD symptoms: intrusion, avoidance and hyperarousal. The images that were shown to the subjects were either "trauma related, generally aversive, pleasant, or emotionally neutral." In this specific experiment, members of the control group were matched with one of the trauma or PTSD victims based on age and sex and both individuals were shown the same type of pictures.

Forty eight pictures were shown to the participants with 12 being trauma relevant, 12 fairly aversive, 12 pleasant and 12 emotionally neutral. The presentation order was randomized so the same category was not presented back to back. The pictures were shown at a size of 120 x 80 cm at a distance of 1.5 m and shown to the participants for 6 seconds. The startle response was a short presentation of a broadband 105-dB[A] white noise. It was given to the subjects

through headphones for 50 ms. This information is important to know because it was additional stress added to the experiment other than just the picture and heart rate, if it had been just those two, the results may have possibly been different (Elsesser et al., 2004).

The results showed that the trauma participants and those diagnosed with PTSD showed accelerated and “specific heart rate reactions” to the stimuli that were presented to them. However, no significant differences emerged between the trauma patients and the PTSD patients (Elsesser et al., 2004). The study provided evidence that people diagnosed with PTSD “exhibit an accelerative evoked HR to trauma-relevant pictures.” The following graphs show their results on heart rate among the four different groups and the three different types of images presented.



Graph 1: Results of HR for the three categories of pictures

The most important graph of these three is the “trauma-related picture” graph. It shows the HR levels among the four groups – the control group, trauma victims without ASD, trauma victims with ASD, and the PTSD group. The control group shows a decrease in heart rate as do the trauma victims who were not diagnosed with ASD. The trauma victims with ASD and the PTSD groups; however show increased heart rate. These two groups almost show a progression towards PTSD and an elevated heart rate. It would be a main goal of our study to be able to track the Soldiers initially from a state of no diagnosis (like the control group) through future deployments to track who developed PTSD and who did not. The HR numbers from the initial test when they had no disorder could then be compared to the progression of a disorder if they

did indeed come back from deployment with one. These results, we propose, would show that those with lower heart rates are most resilient and likely would not show any PTSD diagnoses in the future.

Comparison Metric Study #2

A second study by Pollatos et al. (2007) focused on interoceptive awareness and the participants' heart rate response after being exposed to emotional pictures. The critical element of this study was that of interoceptive awareness or "the extent of a person's sensitivity to bodily signals" (Pollatos et al., 2007). The claim was that an individual who understood his or her body and could detect the signals that it would give, would have a decelerated heart rate when shown the traumatic pictures. Those with higher interoceptive awareness would also believe that the pictures were more arousing. Finally, they claimed that the higher the level of interoceptive awareness, the more decelerated the heart rate would be and the higher the level of arousal the participants would subjectively rate. Essentially, the patients who can most accurately gauge their own heart rate will experience higher levels of arousal when shown emotionally charged pictures

This study consisted of 38 participants, 16 of whom were males, and their average age was 28 years. Half of the subjects had good interoceptive awareness and half had poor interoceptive awareness. A total of 120 pictures with 3 groups of 40 pictures each being neutral, pleasant, and unpleasant were presented. The pictures were shown to the participants at a distance of 1.9 m. and were 75x50 cm in size. The participants were introduced to the pictures for 25s, 35s, and 45s where they were told to count their own heartbeats (the only method allowed) and then record the number of heart beats. They were also asked to fill out a questionnaire about the pleasantness of the pictures and their arousal levels. The actual heart

rates were recorded using an ECG with “nonpolarizable Ag-AgCl electrodes on the right mid-clavicle and lower left rib cage. ECG activity was recorded with a DC amplifier and digitized at a sampling rate of 250 Hz.” (Pollatos et al., 2007)

The study concluded that there is a clear connection with interoceptive awareness and increased cardiovascular reactivity (as indicated by heart rate deceleration) and a higher emotional arousal. The higher heart rates in those with higher interoceptive awareness could potentially show that a better understanding of what one is feeling leads to greater emotions (Pollatos et al., 2007). In our study, this is relevant because it is important to understand how a Soldier perceives one’s own bodily signals. If a Soldier is experiencing a high heart rate, it may indicate a perception of becoming stressed or anxious. Interoceptive awareness could potentially be tested for in the subjective and objective portions of the CSF assessment (Lester, 2009).

Proposed Study Method

Participants

Taking the most applicable parts of these similar studies into consideration, our proposed study design primarily attempts to identify Soldiers who will be resilient to PTSD while at the same time flagging Soldiers that show a higher level of susceptibility to PTSD when exposed to combat. The participants will be U.S. Army Soldiers from eight different brigades who have not been exposed to combat or any extreme traumatic experience prior to the testing. This is a critical part of the testing because Soldiers who previously experienced a traumatic event non-combat related could potentially “reflect the priming effect of earlier traumatization or a combination of inherited vulnerability and lifetime exposure” (Shalev et al., 1998).

Apparatus and Procedure

The test will take place in conjunction with the subjective, objective and physiological portions of the CSF assessment (Lester, 2009). Thirty participants will be in a room at a time, seated at a table with privacy walls on three sides and a computer screen in front of them. The Soldiers will be hooked to an ECG to monitor heart rate and the first stage of the test will be to introduce them to 60 pictures in 3 groups of 20 in random order. There will be 3 different categories of pictures: pleasant, neutral, and extremely traumatic (combat wounds, surgery images, mutilation). The images will be presented to the Soldiers in 10 second intervals. They will then be given 10 minutes to rest and will then be taken into an auditorium where they can be monitored and again will be hooked to an ECG. They will be shown a 5 minute clip containing intensive combat trauma and surgery footage with sound on an image 20 ft. by 10 ft. from a projector, all the while having their heart rate monitored. They will be closely watched for signs such as shutting eyes, looking away, and covering ears which will be reported and taken into account.

This method is expected to reveal Soldiers who exhibit a lower heart rate during exposure to the traumatic images will prove to be more resilient to the effects of PTSD while those showing elevated heart rates could potentially be more susceptible to PTSD. The strengths of this project are seen in the clear correlations among PTSD, traumatic images, and heart rate. Conceptually, the inverse can be taken from these official studies to fit the assessment the Army is looking for in the CSF. We expect the results, compiled over an extended period of time and multiple deployments, show that lower heart rates indicate higher resiliency and suggests that the resiliency training is working.

Analysis and Incorporation into the CSF Assessment Design

As stated previously, a key weakness in the proposed test is due to the complexity of PTSD. There are many factors that go into diagnosing the disorder and Kraemer et al. (2006) concluded that heart rate cannot be used as an independent predictor of PTSD in accidents due to these complexities. Another possible issue in our proposed test is found in the lack of studies on tracking non-PTSD subjects and their resiliency against some future traumatic experience. Most of the current studies are with participants already diagnosed with PTSD and the relationships of heart rate, images, and conditions will have to be formed to fit the new metric. It will take time to gather initial data and then track each Soldier on multiple deployments if heart rate is used as the physiologic variable in the CSF.

The opportunities that this proposed metric provides, however, are found in the other parts of the CSF Assessment design. Through the subjective and objective portions, certain variables (interoceptive awareness and different levels of coping ability) could be tracked in the participants. It would provide physiological data to track the Soldiers' heightened resiliency based on the training they receive.

Annotated References

- Berger, R. & Weiss, T. (2006). Posttraumatic growth in Latina immigrants. *Journal of Immigrant and Refugee Studies*, 4, 55-72.

This study used the Posttraumatic Growth Inventory to assess the growth of Latinas after they experienced the stressful situation of immigration. With an N=100, the findings indicated a moderate level of stress and a high level of PTG.

- Bonanno, G.A. (2004). Loss, trauma, and human resilience: Have we underestimated the human capacity to thrive after extremely aversive events? *American Psychologist*, 59, 20-28.

This article describes the term resilience and how it is differentiated from recovery. The author also describes pathways to resilience which includes hardiness, self-enhancement, repressive coping, positive emotion, and broader conceptualization of stress responding.

- Bonanno, G.A. (2006). Grief, trauma, and resilience. In: E.K. Rynearson (Ed.), *Violent Death: resilience and Intervention Beyond the Crisis* (pp. 31-46). New York: Routledge.

The author speaks of resilience and how it is the capacity for self-stabilization. He speaks about how resilience can be affected by personality dimensions that is then cataloged into two broad categories: flexible adaptation and pragmatic coping. He defines pragmatic coping of a “whatever it takes” response to PTEs.

- Bonanno, G.A., Rennie, C. & Dekel, S. (2005). Self-enhancement among high-exposure survivors of the September 11th terrorist attack: Resilience or social maladjustment? *Journal of Personality and Social Psychology*, 88, 984-998.

This study was focused on comparing the resiliency that people had after experiencing a traumatic event, September 11, 2001. The authors determined that within six months of the event, individuals who lived within the New York Metropolitan area were most resilient to the event.

- Brosschot, J. F. & Thayer, J.F. (2003). Heart rate response is longer after negative emotions than after positive emotions. *International Journal of Psychophysiology* 50, 181-187.
Retrieved May 2, 2010, from <http://www.sciencedirect.com>

According to this article, there is a difference in heart rate between positive and negative emotions. While the intensity of the physiological response may be very similar between exposure to positive and negative emotional experiences, those physiological responses seen with negative emotions last longer, indicating that the type of emotional event can possibly be revealed by the length of the physiological response.

Cadell, S. & Sullivan, R. (2006). Posttraumatic growth and HIV bereavement: Where does it start and when does it end?. *Traumatology*, 12, 45-59.

The study focused on how posttraumatic growth can be enhanced in trauma survivors. This study looked at the PTG of bereaved caregivers of people with HIV/AIDS. A total of 174 participants were surveyed and then interviews were conducted with 15 individuals.

Chappelow, J. W. (1988). Causes of aircrew error in the Royal Airforce. In *Human behaviour in high stress situations in aerospace operations*. NATO AGAARD Conference Proceedings 458.

This study was conducted on the Royal Air Force to see the aircrew's performance errors. The author found that performance improved in a slightly more stressful environment compared to a stress-free environment.

Driscoll, D., Tranel, D. & Anderson, S.W. (2009). The effects of voluntary regulation of positive and negative emotion on psychophysiological responsiveness. *International Journal of Psychophysiology* 72, 61-66.

This article analyzed what happens when a person purposefully tries to regulate both positive and negative emotions. The key result was that when the participant tried to regulate his or her emotions, they experienced a deceleration in heart rate and a greater sense of attention.

Elsesser, K., Sartory, G. & Tackenberg, A. (2004). Attention, heart rate, and startle response during exposure to trauma-relevant pictures: A comparison of recent trauma victims and patients with posttraumatic stress disorder. *Journal of Abnormal Psychology* 113(2), 289-301.

This article shows that individuals who already have PTSD show an increase in heart rate when shown "trauma-related stimuli." Like in the previous article, they found that the increase in heart rate from exposure to these stimuli lasts longer than other responses.

Galea, S., Vlahov, D., Resnick, H., Ahern, J., Susser, E., Gold, J. et al. (2003). Trends of probable post-traumatic stress disorder in New York city after the September 11 terrorist attacks. *American Journal of Epidemiology*, 158, 514-524.

The authors looked at the trends of probable PTSD prevalence in New York City in the six months after September 11 terrorist attacks. They conducted phone surveys at periods of 1 month, 4 months, and 6 months after the traumatic event. The results showed that the prevalence of PTSD declined from 7.5% one month after the attack to .6% six months after the attack.

Heffernon, K., Greal, M. & Mutrie, N. (2009). Post-traumatic growth and life threatening physical illness: A systematic review of the qualitative literature. *British Journal of Health Psychology*, 14, 343-378.

The authors looked to synthesize qualitative data on posttraumatic growth. They focused their study on fifty-seven published journal articles to see if positive change can occur through the experience of trauma and adversity for illness related trauma.

Hoge, C., Auchterlonie, J. & Milliken, C. (2006). Mental health problems, use of mental health services, and attrition from military service after returning from deployment to Iraq or Afghanistan. *Journal of the American Medical Association*, 295, 1023-1032.

The authors conducted population-level screening to see mental health problems among all service members returning from deployment from Afghanistan, Iraq, and other areas. The Soldiers took post deployment health assessments when returning from deployment. Results show there were mental health problems in 19.1% for Iraq, 11.3% for Afghanistan, and 8.5% from other locations.

Jones, F.D. (1995). Psychiatric lessons of war. In: Jones, F.D., Sparacino, L.R., Wilcox, V.L., Rothberg, J.M. & Stokes, J.W. (Eds.), *Textbook of Military Medicine, Part I: War Psychiatry* (pp. 3-33). Washington, D.C.: Office of the Surgeon General, U.S. Army.

This source went into detail of how the U.S. Military has been involved in psychiatry. The authors go over the documented history of military psychiatry from World War I and onward.

Kemeny, M. E. (2003). The psychobiology of stress. *Current Directions in Psychological Science* 12(4), 124-129.

This article discusses the various reactions from stress and the impacts it can have on the body. Sympathetic arousal in the autonomic nervous system as a reaction to stress is shown in many biophysical ways with heart rate being one of them.

Kibler, J.L. & Lyons, J.A. (2004). Perceived coping ability mediates the relationship between PTSD severity and heart rate recovery in veterans. *Journal of Traumatic Stress* 17(1), 23-29.

This article examines combat veterans and shows that there is a linear correlation between heart rate recovery and the severity of their PTSD condition. The study revealed that heart rate recovery was really the “only physiological variable significantly related to PTSD severity.”

Kraemer, B., Moergeli, H. Roth, H., Hepp, U. & Schnyder, U. (2008). Contribution of initial heart rate to the prediction of posttraumatic stress symptom level in accident victims. *Journal of Psychiatric Research* 42, 158-162.

This article states that heart rate is a weak indicator of PTSD when used by itself and should not be an independent predictor of the condition.

Lehner, P., Seyed-Solorforough, M., O'Connor, M., Sak, S. & Mullin, T. (1997). Cognitive biases and time stress in team decision making. *IEEE Trans Systems, Man & Cybernetics*, 27, 698–703.

The authors note that when there is extreme stress, there can be a catastrophic degradation in performance. They showed that when human operators are subjected to extreme stress they ignore proper procedures that they were trained to follow and revert to more familiar and intuitive procedures that bring inferior results.

Lester, P. (2009) Comprehensive Soldier fitness – strong minds and strong bodies – CSF Assessment Overview (slideshow)

This presentation gives an overview of the Army's resiliency testing and training program. It explains the methods of testing, how the assessment will work and provides overviews of the subjective, physiological, and objective assessments as well as relevant research that supports the program goals.

McEwen, B.S. & Stellar, E. (1993). Stress and the individual: Mechanisms leading to disease. *Archives of Internal Medicine*, 153(18), 2093-2101.

The authors present a new relationship between stress and the processes leading to disease. They argue that stress forces the physiologic systems to fluctuate within the body to meet the demands from the stress.

McGrath, J.E. (1976). Stress and behavior in organizations. In: M.D. Dunnette (ed.), *Handbook of Industrial and Organizational Psychology* (pp. 1351-1395). Chicago, IL: Rand McNally.

The author first defined a view of stress as the interaction between three transactional elements of perceived demand, ability to cope, and perceived importance of coping with the demand. This is then linked to a model of psychological stress that conceptualizes stress as an interaction between an individual and his/her environment.

Meichenbaum, D. (2006). Resilience and posttraumatic growth: A constructive narrative perspective. In *Handbook of posttraumatic growth: Research & practice* (pp. 355-367). Mahwah, NJ: Lawrence Erlbaum Associates.

The author focuses on a way to promote posttraumatic growth within trauma victims. He argues that by developing a narrative to that is centered upon posttraumatic growth aids with developing resilience.

Mental Health Advisory Team. (2003). *Operation Iraqi Freedom (OIF). Mental Health Advisory Team (MHAT) Report*. U.S. Army Surgeon General & HQDA G-1. <http://www.armymedicine.army.mil/news/mhat/mhat.cfm>

The Army's Mental Health Advisory Team conducted a study to determine the current mental health status of Soldiers' as well as ways to support those Soldiers in both the short and long-term.

Nagamine, M., Matsuoka, Y. Mori, E., Fujimori, M., Imoto, S., Kim, Y., & Uchitomi, Y. (2007). Relationship between heart rate and emotional memory in subjects with a past history of post-traumatic stress disorder. *Psychiatry and Clinical Neurosciences* 61, 441-443.

This article focuses on the strong evidence that indicates there is a relationship between elevated heart rate and people with a history of PTSD. The findings of the group with a history of PTSD showed that there was a significant positive relationship between heart rate and emotional memory.

Olsson, K.A., Kenardy, J.A., De Young, A.C., & Spence, S.H. (2008). Predicting children's post-traumatic stress symptoms following hospitalization for accidental injury: Combining the Child Trauma Screening Questionnaire and heart rate. *Journal of Anxiety Disorders* 22, 1447-1453.

This study analyzed the ability of the CTSQ and HR to determine whether or not children would experience PTSD after a traumatic accident. They found using both as a predictor was better than using just one or the other.

Pollatos, Olga, Beate M. Herbert, Ellen Matthias, and Rainer Schandry (2007). Heart rate response after emotional picture presentation is modulated by interoceptive awareness. *International Journal of Psychophysiology* 63, 117-124.

This article focuses on interoceptive awareness and states that participants with higher interoceptive awareness reported that the presentations increased their arousal. The findings showed a strong correlation between self-reported heart rate and emotionally charged stimuli.

Resnick, H., Galea, S., Kilpatrick, D. & Vlahov, D. (2004). Research on trauma and PTSD in the aftermath of 9/11. *PTSD Research Quarterly*, 15, 1-8.

The authors examined published studies of trauma and PTSD after 9/11. They found fewer PTSD symptoms in people over time.

Rutter, M. (1987). Psychosocial resilience and protective mechanisms. *American Journal of Orthopsychiatry*, 57, 316-331.

The author discusses mechanisms that protect people from psychological risks. These methods are: reduction of risk impact, reduction of negative chain reactions, establishment and maintenance of self-esteem and self-efficacy, and opening up of opportunities. This is one of the first articles to suggest that resilience protects against traumatic risks.

Shalev, A.Y., Sahar, T., Freedman, S., Peri, T., Glick, N., Brandes, D., Orr, S.P., & Pitman, R.K. (1998). A prospective study of heart rate response following trauma and the subsequent development of posttraumatic stress disorder. *Arch Gen Psychiatry* 55, 553-559.

This article analyzes the relationship between heart rate right after a traumatic event and the possibility of developing PTSD later in life. The research concludes that there is a significant correlation between a higher heart rate right after trauma and the individual developing PTSD later in life.

Sledge, W.H., Boydstun, J.A., & Rabe, A.J. (1980). Self concept changes related to war captivity. *Archives of General Psychiatry*, 37(4), 430-443.

US Air Force Vietnam war (POWs) completed a questionnaire to assess the long-term effects of imprisonment. The results indicated that some POWs reported that the experience was beneficial and this perception was positively related to the severity of the experience.

Solomon, Z. & Dekel, R. (2007). Posttraumatic stress disorder and posttraumatic growth among Israeli ex-POWs. *Journal of Traumatic Stress*, 20, 303-312.

This study was based on how PTSD and PTG can occur from stressful events. The authors conducted a study using Israeli veterans of the 1973 Yom Kippur War in which they filled out a questionnaire. The control group was a group of combat veterans who were not captured. POWs experienced both increased PTSD symptomatology and PTG.

Southwick, S.M., Ozbay, F., Charney, D. & McEwen B.S. (2008). Adaptation to stress and psychobiological mechanisms of resilience. In B.J. Lukey & V. Tepe (Eds.), *Biobehavioral Resilience to Stress* (pp. 91-116). Boca Raton: CRC Press.

This chapter examined resilience from a neurochemical perspective. The authors indicate that resilience can be seen as the ability to minimize allostatic load after a stressor ends.

Stanton, A., Bower, J. & Low, C. (2006). Posttraumatic growth after cancer. In *Handbook of Posttraumatic Growth: Research & Practice* (pp. 138-175). Mahwah, NJ: Lawrence Erlbaum Associates.

The authors talk about how having a cancer diagnosis is a severely traumatic event. Most patients seem to resume normal mood and functioning within a year after medical treatment is completed and some reported positive changes in their lives.

Stein, M.B., Jang, K.L., Taylor, S., Vernon, P.A. & Livesley, W.J. (2002). Genetic and environmental influences on trauma exposure and posttraumatic stress disorder symptoms: a twin study. *Am. J. Psychiatr.*, 159, 1675-1681.

This study examined if there was significant evidence to support the notion that either genetics or environment influences how a person would react to a traumatic event. The evidence showed was that no one variable can be seen as the significant link to PTSD.

Stokes, A. F. & Kite, K. (1994). *Flight Stress: Stress, Fatigue, and Performance, in Aviation*. Burlington, VT: Ashgate.

The authors discuss the role of stress as an external influence that may impact an aviator's performance.

Tedeschi, R.G. & Calhoun, L.G. (1995). *Trauma & transformation: Growing in the aftermath of suffering*. Thousand Oaks, CA: Sage Publications.

The authors focus on the idea that trauma and suffering can allow for a personal transformation thus turning trauma into something more than a negative experience.

Tedeschi, R.G. & Calhoun, L.G. (2006). The foundations of posttraumatic growth: An expanded framework. *Handbook of Posttraumatic Growth: Research & Practice* (pp. 3-23). Mahwah, NJ US: Lawrence Erlbaum Associates.

This article focused on setting a framework for what posttraumatic growth is and how it can be fostered in individuals who have experienced trauma. One method that they suggest is of companionship. This model focuses on the constancy of the companion, humility, and respect for the survivor's story and viewpoint.

Yerkes, R.M. & Dodson, J.D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology* 18, 459–482.

This article compared the relationship between the strength of a stimulus and how a habit is formed. The Yerkes-Dodson curve is critical to explaining the relationship of stress to performance.

Zatzick, D., Russo, J., Pitman, R.K., Rivara, F., Jurkovich, G., & Roy-Byrne, P. (2005). Reevaluating the association between emergency department heart rate and the development of posttraumatic stress disorder: A public health approach. *Society of Biological Psychiatry* 57(1), 91-95.

This article makes the argument that elevated heart rate is a predictor of the development of PTSD. According to their research, a heart rate greater than or equal to 95 beats per minute was a fairly significant predictor of PTSD.

Znoj, H. (2006). Bereavement and Posttraumatic Growth. *Handbook of posttraumatic growth: Research & practice* (pp. 176-196). Mahwah, NJ: Lawrence Erlbaum Associates.

This article describes how a devastating experience like the death of someone close can bring positive changes in a person. The author focused on an experience with parents whose children are suffering from cancer and undergoing severe medical treatment. The results indicated that the best predictors for PTG were adaptive emotion regulation, spiritual coping, and denial.

Zoellner, T. & Maercker, A. (2006). Posttraumatic growth and psychotherapy. In *Handbook of Posttraumatic Growth: Research & Practice* (pp. 334-354). Mahwah, NJ: Lawrence Erlbaum Associates.

The authors argue that posttraumatic growth can be promoted through the use of psychotherapy. By applying psychotherapy, one can nurture positive change by cognitive processing, attempts to master new experiences, and enhance relationships.

Notes

1. LTC McBride, 5 May 2010, assistance given to the authors, West Point, NY at the poster brief. She suggested that the study be done in stages following each deployment by the Soldiers, therefore tracking their progress. This was excellent advice that we incorporated into the paper.
2. LTC Merlo, 5 May 2010, assistance given to the authors, West Point, NY at the poster brief. Our discussion with him helped us see how Graph 1: Traumatic pictures could reveal a progression of Soldiers on multiple deployments as seen in the categories of Constants, Trauma without ASD, Trauma with ASD, and PTSD patients. Trauma without ASD could be similar to resiliency in Soldiers while Trauma with ASD could be similar to a Soldier beginning to develop PTSD.